Effect of TMS (nanostructured silicon dioxide) on growth of Changbai larch seedlings

LIN Bao-shan[1], DIAO shao-qi[2], LI Chun-hui[2], FANG Li-jun[3],QIAO Shu-chun[3], YU Min[3]

[1]*College of Forestry, Beihua University. Jilin City 132011, Jilin Province, P.R China*

[2]*Hongshi Forest Co., Hongshi Town, Huadian County 130000, Jilin Province, P. R. China*

[3] *Fengman District Forestry Bureau, Jilin City 132013, Jilin Province, P. R. China*

Abstract The roots of 200 one-year-old Changbai Larch (*Larix olgensis*) seedlings were soaked for 6 hours at the TMS concentrations of 2000, 1000, 500, 250, 125, and 62 $\mu L \cdot L^{-1}$. Mean seedling height, root collar diameter, main root length and number of lateral roots were measured every 15 days during growing season from May 30 to Oct. 20. Experimental results showed that TMS treatments greatly promoted seedling growth and improved seedling quality. The treatment by 500 $\mu L \cdot L^{-1}$ TMS produced the best result , for which the mean height, root collar diameter, main root length, and the number of lateral roots of seedlings were increased by 42.5 %, 30.7%, 14.0%, and 31.6%, respectively, compared to that of the control seedlings. As to seedling quality, grade-I seedling and grade-II seedlings were fifty-fifty, and no grade-III seedlings was found. The treatment by 500 $\mu L \cdot L^{-1}$ TMS resulted in the highest chlorophyll concentration

Keywords: Changbai Larch; *Larix olgensis;* Seedling production, Nanostructured silicon dioxide

CLC number: S143.8 **Document code**: B **Article ID**: 1007-662X(2004)02-0138-03

Introduction

TMS is nanostructured silicon dioxide manufactured by Beijing Luming Institute of Biotechnology and used as a plant regulator. Nanostructured silicon dioxide can form a binary film at cell wall after absorption, which can prevent the infection of fungi,, bacteria, and nematode, reduce plant transpiration, increase disease resistance, and improve plant growth under the stresses of high temperature and humidity. Disease is a major threat to seedling production. Nanostructured silicon dioxide can greatly enhance cell wall rigidity (Wang 2002b) and improve plant resistance to stresses including disease, low temperature, and drought (Wang 1999).

Silicon is an element required in number of metabolic and physiological activities in plants. Research shows that application of silicon fertilizer in silicon-deficient soil can promote plant growth, enhance resistance to disease, cold, and heavy metals of manganese, iron, aluminum, and copper, and increase photosynthesis. Silicon fertilization promotes the absorption of potassium and restricts the absorption of sodium, which therefore increases potassium/sodium selection ratio, helps the accumulation of potassium, nitrogen, and sulphur in plants, and improves plant nutrition (Wang 2001, 2002a; Liu 2003; Guo 2000; Jiang *et al.* 2002a; 2002b).

In recent years, silicon fertilizer is widely used to increase production and to enhance plant stress resistance in agricultural crops (wheat, corn, peanut, and cereal crops), vegetable production (cucumber and radish), and fruit tree cultivation (cherry and apple). In production of forest seedlings, nanostructured silicon dioxide can promote seedling growth and root development and increase resistance to disease. Research in the USA shows that addition of silicon in conifer tissue culture promotes seedling growth (Emadian 1989). However, little information is available on the effects of nanostructured silicon dioxide on tree growth in both physiological research and field experiments. The mechanism of how nanostructured silicon dioxide affects tree growth is not clear. The objective of this study is to determine the effects of nanostructured silicon dioxide in larch seedling production. The experiment was carried out in Hongshi Forest Co. and expected results were obtained.

Materials and methods

Experimental site is located at Dongxing Forest Nursery, Hongshi Forest Co. Annual mean temperature is 4.5 °C, Ten year-mean cumulative temperature above 5 °C is 2578 °C. The frost-free period is 140 days. Mean annual precipitation is 900 mm. Soil type is dark forest soil. Seedbed is 1 m x 10 m, orientated at north-south direction.

The experimental materials were one-year old Changbai larch (*Larix olgensis*) seedlings. Roots were soaked for 6 hours at the TMS concentrations of 2000, 1000, 500, 250, 125, 62 $\mu L \cdot L^{-1}$ and 0 $\mu L \cdot L^{-1}$ (no TMS control). Two hun-

Foundation item: This study is supported by Jilin Forestry Group Co.

Biography: LIN Baoshan (1955-), male, Associate professor at the college of forestry, Beihua University, Jilin City 132011, Jilin Province, P.R China. E-mail: linbaoshan@eyou.com

Received date : 2004-03-06

Responsible editor: Chai Ruihai

dred seedlings were treated at each concentration and a total of 1400 seedlings uniform in size were used. There were four blocks and each block contained 7 treatments (6 treated groups and 1 untreated control). The purpose of blocking was to minimize the systematic errors caused by the change of soil condition.

Each of the planted seedlings was measured for height and RCD (root collar diameter) at the time of planting. Then measurement was carried out every half month until harvest on October 20 when main root length and number of lateral roots were determined.

Results

Seedling growth

Mean seedling height, RCD, main root length, and number of lateral roots calculated from 200 treated seedlings were shown in Table 1. Fast increase in both height and RCD occurred in late July (Table 1). The increased growth stops in late August and RCD growth completes in mid-September.

Table 1. Measurements of growth of *Larix olgensis* seedlings treated with different concentrations of TMS (nanostructured silicon dioxide) (n=200)

Concentration of TMS / $\mu L \cdot L^{-1}$	May 30 Mean height	May 30 Mean RCD	June 15 Mean height	June 15 Mean RCD	June 30 Mean height	June 30 Mean RCD	July 15 Mean height	July 15 Mean RCD	July 30 Mean height	July 30 Mean RCD
62	10.1	0.17	11.7	0.20	16.0	0.24	20.1	0.26	28.1	0.32
130	10.7	0.18	11.7	0.22	16.1	0.24	21.1	0.27	28.4	0.31
250	8.5	0.16	9.9	0.20	15.6	0.23	19.6	0.26	29.2	0.32
500	8.8	0.17	11.0	0.20	18.5	0.24	23.8	0.29	33.6	0.34
1000	9.6	0.20	12.0	0.23	17.6	0.28	21.5	0.30	30.8	0.38
2000	9.7	0.17	11.0	0.21	15.4	0.23	19.3	0.24	27.9	0.32
Control	8.5	0.15	9.8	0.18	13.0	0.22	16.1	0.22	23.4	0.27

Concentration of TMS / $\mu L \cdot L^{-1}$	Aug 15 Mean height	Aug 15 Mean RCD	Aug 30 Mean height	Aug 30 Mean RCD	Sep15 Mean height	Sep15 Mean RCD	Sep 30 Mean height	Sep 30 Mean RCD	Roots on Oct 20 Main root length	Roots on Oct 20 Number of lateral roots
62	30.7	0.36	31.3	0.39	31.5	0.42	31.5	0.43	45.0	9
130	33.9	0.34	35.6	0.39	37.0	0.44	37.6	0.45	47.0	9
250	30.7	0.35	35.7	0.41	35.9	0.45	35.9	0.45	52.0	8
500	38.4	0.36	40.1	0.42	40.3	0.47	40.3	0.48	52.5	10
1000	35.3	0.43	37.0	0.48	37.3	0.51	37.3	0.51	50.0	11
2000	32.2	0.36	34.3	0.43	34.3	0.46	34.3	0.46	48.0	9
Control	26.7	0.31	28.7	0.35	28.7	0.38	28.7	0.38	46.0	8

Fifty seedlings were randomly selected from the total of 200 seedlings for the treatment of 500 $\mu L \cdot L^{-1}$ TMS and the control treatment. Height, RCD, main root length, and number of lateral roots were measured on each of the sampled seedlings for statistical comparison. Student t test was used to compare the difference between the 500$\mu L \cdot L^{-1}$ treatment (x_1) and untreated control (x_2).

$$t = (\bar{x}_i - \bar{y}_i)/\mathrm{sqrt}(S_{x_i}{}^2/n + S_{y_i}{}^2/n)$$

The calculated t values are 13.90 for the height of seedling, 6.69 for RCD, 6.83 for main root length, and 6.45 for the number of lateral roots. All the calculated t values are greater than the critical t value at 0.01 level (2.66), indicating a significant difference between 500$\mu L \cdot L^{-1}$ treatment and the control. The treatment of 500$\mu L \cdot L^{-1}$ TMS produced the best result , for which the mean height, root collar diameter, main root length, and the number of lateral roots were increased by 42.5%, 30.7%, 14.0%, and 31.6%, respectively, compared to the control seedlings (Tables 2).

Chlorophyll content

Chlorophyll content was determined from the mid-crown needles of 15 seedlings randomly sampled from 50 seedlings of each treatment. The mean chlorophyll concentration is presented in the Table 3. The treatment by 500 $\mu L \cdot L^{-1}$ TMS resulted in the highest chlorophyll concentration. Visual assessment also indicates that the needles of seedlings treated by 500$\mu L \cdot L^{-1}$ TMS were darker in color than other treatments.

Economic analysis

The planting density of transplanted Changbai larch seedlings is 250/m^2. Seedling grading system requires >35 cm in height and >0.5 cm in RCD for grade I seedlings, 25-35 cm in height and 0.35-0.5 cm in RCD for grade II seedlings, and <25 cm in height and <0.35 cm in RCD for grade III seedlings. The 500 $\mu L \cdot L^{-1}$-treated group produces 50% seedling in grade I, 50% in grade II, and 0% seedlings in grade III, while no-TMS control group has 0% seedling in grade I, 54% in grade II, and 46% in grade III. The growth

of best seedlings in the control group is equivalent to that of poorest TMS-treated seedlings. The grade I seedlings are priced at 0.17-0.20 Yuan/seedling and grade II at 0.12-0.15 Yuan/seedling. The economic gain is therefore 12.50 Yuan/m^2 based on the calculation of the seedling density of 250/m^2. TMS is sold at 0.01 Yuan/g and therefore, the cost of using TMS in seedling production is 0.015 Yuan/ m^2. The provincial government requires that grade III seedling can not be used for plantation and another year of cultivation at nursery is needed. All the 2-year old transplants reach grade II standards under TMS treatment, so TMS treatment lead to a significant economic benefit.

Table 2. Statistical comparison on growth between seedlings treated with 500 μL·L^{-1} TMS and those in control group

	Growth of seedlings treated with 500 μL·L^{-1}					Growth of seedlings in control			
Seedlings (n=50)	Height / cm	RCD /cm	Main root length /cm	Number of lateral roots	Seedlings (n=50)	Height /cm	RCD /cm	Main root length /cm	Number of lateral roots
Mean $\bar{x}_i$	40.87	0.4896	52.89	10.82	Mean $\bar{y}_i$	28.68	0.3746	46.38	8.22
STDEV S_{x_i}	5.106	0.100	5.934	2.362	STDEV S_{y_i}	3.519	0.069	3.187	1.595

Table 3. Chlorophyll content (mg/g Fresh Weight, N=15)

Concentration of TMS / μL·L^{-1}	665 Wavelength	645 Wavelength	Chlorophyll a	Chlorophyll b	Total (a+b)
Control	0.9	0.44	0.25616	0.1466	0.40276
62	1.8	1.1	0.497525	0.41915	0.916675
125	3.6	2.1	1.001775	0.78105	1.782825
250	8.5	4.2	2.4163	1.41	3.8263
500	11.2	5.2	3.2063	1.6666	4.8729
1000	5.6	3.8	1.52245	1.5203	3.04275
2000	2.4	1.3	0.674575	0.46345	1.138025

Conclusions

The best TMS concentration for larch seedling production is 500μL·L^{-1} with root dipping for 6 hours;

Seedlings treated TMS have 50% in grade I, 50% in grade II, and 0% in grade III. Two-year old seedlings can all meet the standards for field planting;

There is a significant economic gain with the use of TMS in larch seedling production.

References

Guo Zhongman. 2000. Synthesis of the needle-like silica nanoparticles by biomineral method [J]. Chemical Journal of Chinese Universities, **21**(6): 847-848.

Jiang Jun-ping. 2002a. Nutrition of turfgrass soils testing and diagnosis in golf courses [J]. Plant Nutrition and Fertilizer Science, **8**(4): 497-500.

Jiang Jun-ping. 2002b. Physical and chemical properties and diagnosis of turf soils in golf courses [J]. Acta Agrestia Sinica, **10**(1): 59-62.

Liu Jun-bo. 2003. The development and application nano silicon dioxide [J]. Journal of Changchun University of Technology, **24**(12): 9-12.

Wang Lijun. 2001. Relationship between nanostructure SiO_2 and occurrence of plant fungi [J]. Journal of Huazhong Agricultural University, **20**(6): 593-597.

Wang Lijun. 2002a. Self-assembled biomineralized structures constructed in plant cell walls [J]. Acta Chimica Sinica, **60**(6): 1144-1146.

Wang Lijun. 2002b. Synthesis of Ordered Biosilica Materials [J]. Chinese Journal of Chemistry, **20**(2): 107-110.

Wang Lijun. 1999. Biomineralized nanostructured materials and plant silicon nutrition [J]. Progress in Chemistry, **11**(2), 119-128.